LIGHT COUPLING MECHANISMS IN QUANTUM WELL INFRARED PHOTODETECTOR FOCAL PLANE ARRAYS

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Quantum Well Infrared Photodetectors (QWIPs) do not absorb radiation incident normal to the surface since the light polarization must have an electric field component normal to the superlattice (growth direction) to be absorbed by the confined carriers [1]. When the incoming light contains no polarization component along the growth direction, the matrix element of the interaction vanishes (i.e., $\vec{\varepsilon}.\vec{p}_z = 0$ where $\vec{\varepsilon}$ is the polarization and $\vec{p}_z$ is the momentum along z direction). As a consequence, these detectors have to be illuminated through a 45° polished facet [1]. Clearly, this illumination scheme limits the configuration of detectors to linear arrays and single elements. For imaging, it is necessary to be able to couple light uniformly to two dimensional arrays of these detectors. Several different monolithic grating structures [1], such as linear gratings, two-dimensional (2-D) periodic gratings, and random-reflectors have been demonstrated for efficient light coupling to QWIPS, and has made two dimensional QWIP imaging arrays [2] feasible. These gratings deflect the incoming light away from the direction normal to the surface, enabling intersubband absorption. All these gratings were fabricated on the detectors by using standard photolithography and selective dry etching. The advantage of the photolithograpic process is its ability to accurately control the feature size and to preserve the pixel-to-pixel uniformity, which is a prerequisite for high-sensitivity imaging focal plane array (FPA). However the resolution of the photolithography and the accuracy of etching processes become key issues in producing smaller grating feature sizes. These feature sizes are proportionally scaled with the peak response wavelength of the QWIP. It is important to note that for any given wavelength the random grating requires much smaller feature sizes than two dimensional periodic gratings. Thus the random reflectors of the 9 μm cutoff FPA were less sharp and had fewer scattering centers compared to 15 μm cutoff FPA and this is due to the difficulties associated with sub-micron photolithography. These less sharp features in random gratings lowered the light coupling efficiency than expected. Thus, it could be advantageous to utilize a 2-D periodic grating for light coupling in shorter wavelength QWIPs.

Six different 2-D grating periods were fabricated on a standard QWIP structure designed to perform at peak wavelength , λ_p -8.5 pm. In order to fabricate three QWIP samples with three different grating groove depths for each grating period, the top cap layer of each sample was thinned down to a different thickness by chemical etching. As a control sample, a standard 45° edge polished facet sample was also fabricated from the original QWIP wafer. We have observed an enhancement factor of three due to 2D periodic grating fabricated on QWIP structure. Variation of the enhancement factor with groove depth and feature size of the grating can be theoretically explained. However the resolution of the photolithography and accuracy of the etching become key issues in producing smaller grating feature sizes especially in shorter wavelengths. Unlike random reflectors the tight coupling efficiency of two dimensional (2-D) gratings strongly depends on the wavelength and thus exhibits narrow band width spectral responses. Therefore, 2-D gratings can be utilized to select narrow spectral bands m multi color QWIP cameras.

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